THE INTEGRATION OF COGENERATION AND SPACE COOLING

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ABSTRACT

Cogeneration is the production of electrical and thermal energy from a single fuel source. In comparison, electric power generation rejects the useful heat energy into lakes or other heat sinks. Electric generation alone provides approximately 30 percent of its prime energy for useful end-use energy, while cogeneration makes approximately 80-85 percent of its prime energy source available for useful work (Figure A). The application of the thermal energy is critical to the economic analysis of a cogeneration project since nearly two-thirds of the energy and economic savings are produced by the hot water and/or exhaust gases. Finding a productive and economical application for the thermal energy is extremely important.

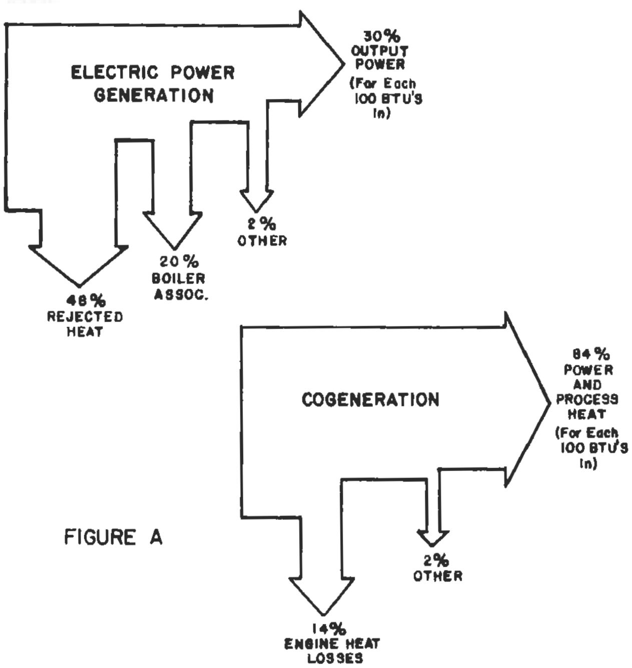

FIGURE A

Historically, thermal energy from cogeneration systems is principally used as hot water or steam. Space cooling by either absorption units or a desiccant system has added a new dimension of usefulness for cogenerated thermal energy. Cogeneration is now applied to large office buildings, grocery stores, restaurants, hotels, schools, or other commercial facilities.

While producing thermal energy, the cogeneration system also produces electricity (Figure B). The electricity produced is used to reduce purchased electrical energy. In many cases, the energy to operate a cogeneration engine can be purchased at cost sufficient to produce electricity near the cost of purchased electricity. Therefore, all the thermal energy or its associated space cooling is essentially cost free.

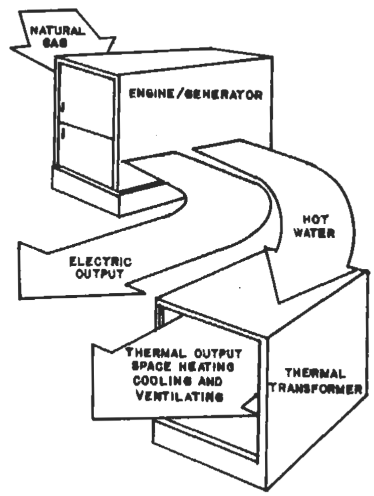

FIGURE B

In hot and humid climates, both air conditioning and humidity control are required. The thermal output of a cogeneration unit provides the heat necessary to power an absorption chiller and/or a desiccant dehumidification system. The integration of cogeneration and space cooling systems can be beneficial for both the cogeneration and absorption or dehumidification equipment. It can also be financially and energy successful for the owner of a cogeneration cooling system.

NEW MARKET FOR OLD TECHNOLOGIES

If you look into the heart of some older buildings, you will find an aging mechanical system ready for replacement with newer, more efficient equipment. The 1950s and 1960s saw the use of "total energy" or cogeneration for large building complexes such as hospitals and universities. The same time period also witnessed the use of absorption chillers to provide much of the buildings' space cooling. By the 1970s, many of these systems began to be replaced with electric equipment due to the cheap cost of purchased electricity. Today, in the 80s, "cheap energy" does not exist. Mechanical equipment has and is undergoing changes to make it more energy efficient.

New absorption chillers are twice as efficient as the original units, but they are also more expensive. Marketing them is dependent upon cost efficient operation and finding new applications for

Proceedings of the Fourth Symposium on Improving Building Systems in Hot and Humid Climates, Houston, TX, September 15-16, 1987

them. Presently, approximately 55,000 tons of new double effect absorption chiller/heaters are in operation within the U.S.; 10,000 tons are operating in the Gulf Coast, a hot and humid climate area.

Cogeneration saw a resurgence in the early 1980s, but its growth was limited mostly to industrial plants, especially the petrochemical industries. Now, the late 80s are seeing smaller, pre-packaged, cogeneration systems being designed, marketed, and installed at hospitals, hotels, restaurants, and other commercial establishments.

Cogeneration, to be economically viable, requires the constant use of its thermal output. Many commercial facilities do not need large continuous quantities of hot water. Integrating the cogenerated hot water with systems that are able to transform the hot water energy into air conditioning and heating energy would not make cogeneration applicable to more types of business but also make the cooling system more marketable.

THE THERMAL VALUE

Two critical factors make cogeneration viable: 1) A high differential cost between the fuel for cogeneration and the local electric rate, and 2) the full use of the thermal output while supplementing a portion of the electrical energy. The greater the differential between the fuel cost and the electric rate, the more savings incurred on the electrical output of the cogenerator. Fuel cost is calculated as:

cost/MMBTU x fuel consumption in
MMBTU/hr. x hours of operation

Electrical savings is calculated as:

electric rate/KWH x KW output x hours
of operation

If the electric rate has a demand charge and/or a rachet clause, these also must be figured into the electric cost savings calculation. Demand charge is a monthly charge based on the maximum electrical power used within short time spans, generally fifteen minutes, throughout the month. If 100 KWs is the maximum power used during only one fifteen-minute period in the month and all other fifteen-minute periods use 50 KWs, the month's demand charge would be based on the 100 KWs and would be calculated as:

cost/KW x maximum KW

A ratchet clause says that the minimum monthly demand billing will be calculated as the greater of: 1) the actual monthly demand charge, as above, or 2) a percentage of the maximum month's demand billing over a yearly time span. Example: If July's demand is 100 KW and April's is 40 KW, and an 80 percent ratchet is in effect, then the bill would be calculated as:

100 KW x .8 x cost/KW = 80 KW x cost/KW

and not as:

40 KW x cost/KW

Gas rates in 1987 generally will result in a fuel operation cost that is equal to or slightly less than the electrical reduction savings. On this basis, all other energy produced by cogeneration is "free energy" or savings to the facility's operation. The thermal energy from cogeneration accounts for nearly two-thirds of the energy output and two-thirds of the operation savings. A 100 KW reciprocating cogeneration engine produces approximately 195 KWs worth of hot water. Using the full output of the cogeneration unit for 500 hours per month results in a $3,000 electric monthly cost reduction and a $5,850 electric water heating monthly savings at $.06/KWH. An $8,850 reduction in the electric bill is achieved. However, if full thermal output can not be used, total savings are quickly reduced. Assuming a 50 percent thermal output utilization, thermal savings become $2,925 and overall savings becomes $5,925, a 33 percent reduction (computer analysis project sheets 1 and 2).

Most commercial establishments do not require large amounts of hot water and therefore, are not prime customers for cogeneration. Usually, only motels, apartments, laundry facilities and hospitals are considered good users of hot water and therefore prime cogeneration prospects. The field has been limited. Now however, with the inclusion of absorption chillers and desiccant dehumidifiers, the hot water from cogeneration can be used to provide air conditioning. In hot and/or humid climates this is a major operational advantage.

A 100 KW cogeneration unit operating 6,000 hours per year without a thermal requirement saves only $36,000 per year at $.06/KWH electricity. The use of the thermal hot water to produce 35 tons of absorption chiller cooling saves an additional $18,000 per year, and with the desiccant system providing 60 tons of latent cooling, $32,400 is saved (computer analysis project sheets 3, 4, & 5).

The use of the thermal value of cogeneration is vital to successful cogeneration savings. It is approximately 66 percent of the savings as well as the energy produced. If all the thermal energy is used to replace electric water heating, total savings are maximized; thermal load used for air conditioning provides a high level of savings; thermal energy used to replace gas water heating provides nominal savings, and the non-use of thermal energy provides little to non existing savings. <u>To make cogeneration practicable, the thermal output must be used.</u> Second, in importance, is the differential in fuel and electric rates. A low differential will reduce savings; a high differential will increase savings.

INTEGRATING THE ABSORPTION CHILLER WITH COGENERATION

An absorption chiller utilizes an absorbent, water, and low pressure to cool circulated water to a fan coil unit. Under low pressure, water has excellent refrigeration properties. A heat medium is required to boil off the refrigerant vapors from the absorbent solution. This heat may be suppled by gas fired boiler or, in the case of cogeneration, by hot water (Figure C). The hot water from the cogenerator can be routed directly to the fan coil unit for space heating. A four-pipe sytem is able to provide cooling and heating simutaneously from the cogen-chiller system.

ABSORPTION CHILLER/HEATER

HEAT ENERGIZED COOLING & HEATING SYSTEM (COOLING OPERATION)

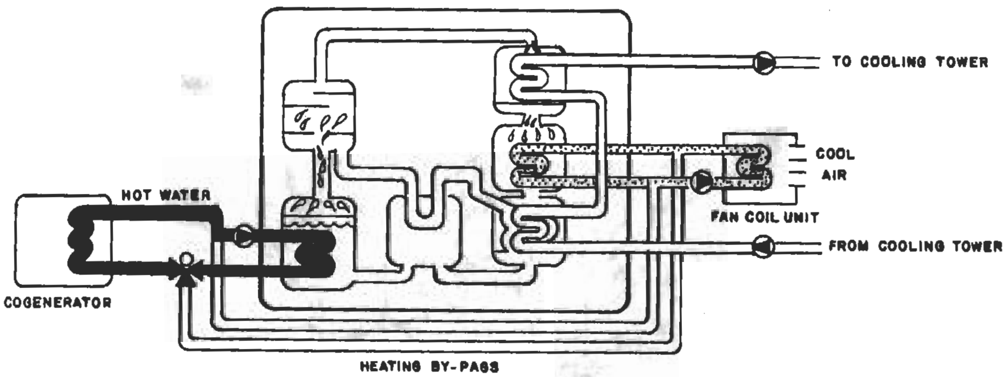

FIGURE C

The rated water flow and T from the cognerator must be matched with the flow and T of the chiller. Maximum temperature from the cogenerator will result in increased cooling from the absorption unit. To analyze the tonnage of cooling provides by cogenerated hot water:

1. Match cogeneration heat output to the heat input required of the chiller to obtain a nominal tonnage.

2. Calculate the capacity factor based on cogeneration exit/chiller entering temperature.

3. Multiply the tonnage by the capacity factor to obtain the actual tonnage the cogeneration thermal load is able to replace.

Another analysis is to use the hot water flow rate and T of the cogenerator to calculate the chiller input heat energy:

8.33 x 60 min./hr. x T x flow rate (gpm)

= Btu/hr.

The location of the cogenerator to the chiller should be kept as close as possible to reduce pumping and thermal losses. A closed expansion tank should be installed to pressurize the line between the two units.

Savings, using the system, are average to good -- better than replacing a gas boiler on the thermal load, but worse than replacing electric heating. The cost of this system is appreciably higher than others, because of the absorption chiller cost, especially the better more efficient double-effect chiller and the water tower expense. Paybacks are about the same as those where gas-fired thermal loads are replaced by cogeneration alone. However, the technology is proven; and with rebates or significant electric rate increases, a cogen-chiller system is a practical installation.

INTEGRATING THE DESICCANT DEHUMIDIFIER WITH COGENERATION

In the Gulf Coast, area humidity is as much a problem as the heat. Air conditioning systems must work as hard dehumidifying the air as cooling it. Up to 40 percent of the cooling load can be latent heat. Rather than using a compressor, a desiccant unit uses two rotating "wheels" to remove humidity and heat for air conditioning. Because thermal energy is managed through various transfer sequences to provide comfort conditioning of air, it can be considered a thermally actuated heat pump. Desiccant technology is over thirty years old with increased research efforts in this decade.

The heart of a desiccant unit is the desiccant and the heat exchanger. Intake air is passed over and the desiccant and absorbant compound, generally lithium chloride, which absorbs the moisture from out of the air resulting in hot dry air. This hot dry air is passed across a heat exchanger producing warm dry air which can then be either sensibly cooled across a freon coil or across an evaporative element to produce cooling. If heating is required, the air from the desiccant is passed directly into the space to be heated, bypassing the heat exchanger and the cooling elements. Return air picks up the heat from the heat exchanger; more heat is added as necessary to raise its temperature to 180-190°F., which then allows the hot air to "dry out" the desiccant for reuse on the inlet air. Providing the extra heat necessary to the return air for drying, the desiccant is the integration of cogeneration into the system (Figure D).

for summer; but the desiccant system also provides dehumidification, which is a refrigeration area reduces defrosting, lowers electrical load, keeps produce more viewable, and provides a more comfortable shopping climate (Figure E).

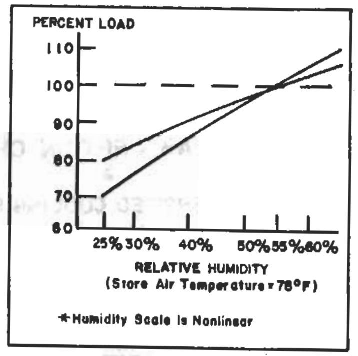

FIGURE E

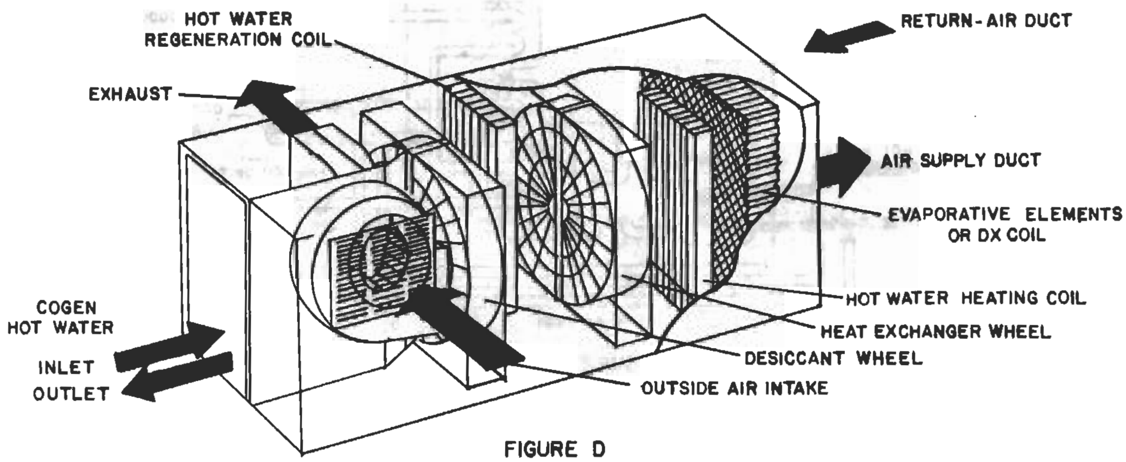

FIGURE D

In the past, boilers were used to provide hot water to the regeneration coil for heating the return air to a sufficient temperature to dry the desiccant. Cogenerated hot water is able to do the same job, eliminate the boiler cost and its associated fuel input, and provide a quantity of electricity to reduce the facility's purchased electrical power. It is the thermal cogenerated energy though that provides the true savings through the reduction of electrical air conditioning operation cost. This savings can be calculated by:

1. Matching the cogenerated thermal load to the desiccant's required regeneration load, and reading the tonnage from the desiccant dehumidifier's spec sheet.
2. This tonnage, if being used with a DX coil, should not exceed 40 percent of the building's total load.

In the same way as sizing the load on an absorption chiller, calculating the cogenerator's hot water flow and ΔT will provide the available heat energy to a desiccant unit; and knowing the required regeneration load per unit will determine the number of units the cogenerator can support.

This system, as with the absorption chiller, is able to provide both heating for winter and cooling

Grocery, fast food, and convenience stores are finding the advantages of cogen-desiccant systems very economical and energy saving.

SUMMARY

Cogeneration is on the energy forefront because of its energy and economic savings. Though it is not applicable everywhere, because it requires a substantial thermal load and many facilities do not have a large hot water or space heating loads especially in the southern states, cogeneration is practical when integrated with an absorption chiller or desiccant dehumidifier equipment. The southern states require high cooling load as well as dehumidification. The cogeneration unit is made more viable by the cooling/desiccant equipment and the cooling/desiccant equipment gain, a new marketing tool in cogeneration. This integration of equipment is another example of American ingenuity leading the way through innovative use of existing technologies.

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COGENERATION SCREENING ANALYSIS

DATA PROJECT 1

16-Jun-87

by: JIM PHILLIPS

EQUIPMENT DATA:		ENERGY DATA:	
Generator Size:	100 KW	Gas Rate:	$3.50 per MCF
Recoverable Heat:	0.666 MMBH	Cogen Rate:	$3.50 per MCF
Fuel Consumption:	1.235 MCFH	Electric Rate	
Maintenance Cost:	$1.00 per Hour	Demand:	$0.00 per KW
Hours of Electric		Months:	0 Months
Operation:	6000 Hours per Year	Energy:	$0.0600 per KWH
Hours of Thermal			(FCA incl'd.)
Operation:	6000 Hours per Year	% Gas Thermal:	0 %
		% Electric Thermal	100 %
Estimated Cost:	$120,000 Installed	Chiller Tonnage:	0 Tons
		Chiller Eff.:	0 KW/Ton

AVOIDED ELECTRIC ENERGY COSTS:

DEMAND: ELECTRIC DEMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION= $0.00

ENERGY: ELECTRIC ENERGY RATE * GENERATOR SIZE * HOURS OF ELECTRIC OPERATION= $36,000.00

AVOIDED THERMAL ENERGY COSTS:

GAS PRODUCED: GAS RATE * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION= $0.00

ELECTRIC HEATING: ELECTRIC ENERGY RATE * 293 KWH/MMBH * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION + ELECTRIC DAMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION= $70,249.68

ELECTRIC COOLING: ELECTRIC ENERGY RATE * CHILLER TONS * KW/TON * HOURS OF THERMAL OPERATION + ELECTRIC DEMAND RATE * CHILLER TONS * KW/TON * MONTHS OF OPERATION= $0.00

COGENERATION COSTS:

FUEL: COGEN RATE * CONSUMPTION/HOUR * HOURS OF ELECTRIC OPERATION= $25,935.00

MANITENANCE: MAINTENANCE COST/HOUR * HOURS OF ELECTRIC OPERATION= $6,000.00

COGENERATION SAVINGS/YEAR: SUM OF AVOIDED COSTS - COGENERATION COSTS= ====> $74,314.68

PERCENT SAVINGS => 69.94% SIMPLE PAYBACK: ====> 1.61 YEARS

COGENERATION SCREENING ANALYSIS

DATA PROJECT 2

16-Jun-87

by: JIM PHILLIPS

EQUIPMENT DATA:		ENERGY DATA:	
Generator Size:	100 KW	Gas Rate:	$3.50 per MCF
Recoverable Heet:	0.666 MMBH	Cogen Rate:	$3.50 per MCF
Fuel Consumption:	1.235 MCFH	Electric Rate	
Maintenance Cost:	$1.00 per Hour	Demand:	$0.00 per KW
Hours of Electric		Months:	0 Months
Operation:	6000 Hours per Year	Energy:	$0.0600 per KWH
Hours of Thermal			(FCA incl'd.)
Operation:	3000 Hours per Year	% Gas Thermal:	0 %
		% Electric Thermal	100 %
Estimated Cost:	$120,000 Installed	Chiller Tonnage:	0 Tons
		Chiller Eff.:	0 KW/Ton

AVOIDED ELECTRIC ENERGY COSTS:

DEMAND: ELECTRIC DEMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION= $0.00

ENERGY: ELECTRIC ENERGY RATE * GENERATOR SIZE * HOURS OF ELECTRIC OPERATION= $36,000.00

AVOIDED THERMAL ENERGY COSTS:

GAS PRODUCED: GAS RATE * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION= $0.00

ELECTRIC HEATING: ELECTRIC ENERGY RATE * 293 KWH/MMBH * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION + ELECTRIC DAMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION= $35,124.84

ELECTRIC COOLING: ELECTRIC ENERGY RATE * CHILLER TONS * KW/TON * HOURS OF THERMAL OPERATION + ELECTRIC DEMAND RATE * CHILLER TONS * KW/TON * MONTHS OF OPERATION= $0.00

COGENERATION COSTS:

FUEL: COGEN RATE * CONSUMPTION/HOUR * HOURS OF ELECTRIC OPERATION= $25,935.00

MANITENANCE: MAINTENANCE COST/HOUR * HOURS OF ELECTRIC OPERATION= $6,000.00

COGENERATION SAVINGS/YEAR: SUM OF AVOIDED COSTS - COGENERATION COSTS=

===> $39,189.84

PERCENT SAVINGS => 55.10% SIMPLE PAYBACK: =========================> 3.06 YEARS

COGENERATION SCREENING ANALYSIS

DATA PROJECT 3

16-Jun-87

by: JIM PHILLIPS

EQUIPMENT DATA:		ENERGY DATA:	
Generator Size:	100 KW	Gas Rate:	$3.50 per MCF
Recoverable Heat:	0.666 MMBH	Cogen Rate:	$3.50 per MCF
Fuel Consumption:	1.235 MCFH	Electric Rate	
Maintenance Cost:	$1.00 per Hour	Demand:	$0.00 per KW
Hours of Electric		Months:	0 Months
Operation:	6000 Hours per Year	Energy:	$0.0600 per KWH
Hours of Thermal			(FCA incl'd.)
Operation:	0 Hours per Year	% Gas Thermal:	0 %
		% Electric Thermal	100 %
Estimated Cost:	$120,000 Installed	Chiller Tonnage:	0 Tons
		Chiller Eff.:	0 KW/Ton

AVOIDED ELECTRIC ENERGY COSTS:

DEMAND:	ELECTRIC DEMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION=	$0.00
ENERGY:	ELECTRIC ENERGY RATE * GENERATOR SIZE * HOURS OF ELECTRIC OPERATION=	$36,000.00

AVOIDED THERMAL ENERGY COSTS:

GAS PRODUCED:	GAS RATE * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION=	$0.00
ELECTRIC HEATING:	ELECTRIC ENERGY RATE * 293 KWH/MMBH * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION + ELECTRIC DAMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION=	$0.00
ELECTRIC COOLING:	ELECTRIC ENERGY RATE * CHILLER TONS * KW/TON * HOURS OF THERMAL OPERATION + ELECTRIC DEMAND RATE * CHILLER TONS * KW/TON * MONTHS OF OPERATION=	$0.00

COGENERATION COSTS:

FUEL:	COGEN RATE * CONSUMPTION/HOUR * HOURS OF ELECTRIC OPERATION=	$25,935.00
MANITENANCE:	MAINTENANCE COST/HOUR * HOURS OF ELECTRIC OPERATION=	$6,000.00

COGENERATION SAVINGS/YEAR: SUM OF AVOIDED COSTS - COGENERATION COSTS=
=====> $4,065.00

PERCENT SAVINGS => 11.29% SIMPLE PAYBACK: =====> 29.52 YEARS

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COGENERATION SCREENING ANALYSIS

DATA PROJECT 4

16-Jun-87

by: JIM PHILLIPS

EQUIPMENT DATA:		ENERGY DATA:	
Generator Size:	100 KW	Gas Rate:	$3.50 per MCF
Recoverable Heat:	0.666 MMBH	Cogen Rate:	$3.50 per MCF
Fuel Consumption:	1.235 MCFH	Electric Rate	
Maintenance Cost:	$1.00 per Hour	Demand:	$0.00 per KW
Hours of Electric Operation:	6000 Hours per Year	Months:	0 Months
		Energy:	$0.0600 per KWH (FCA incl'd.)
Hours of Thermal Operation:	6000 Hours per Year	% Gas Thermal:	0 %
		% Electric Thermal	100 %
Estimated Cost:	$120,000 Installed	Chiller Tonnage:	35 Tons
		Chiller Eff.:	1.5 KW/Ton

AVOIDED ELECTRIC ENERGY COSTS:

DEMAND:	ELECTRIC DEMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION=	$0.00
ENERGY:	ELECTRIC ENERGY RATE * GENERATOR SIZE * HOURS OF ELECTRIC OPERATION=	$36,000.00

AVOIDED THERMAL ENERGY COSTS:

GAS PRODUCED:	GAS RATE * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION=	$0.00
ELECTRIC HEATING:	ELECTRIC ENERGY RATE * 293 KWH/MMBH * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION + ELECTRIC DAMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION=	$0.00
ELECTRIC COOLING:	ELECTRIC ENERGY RATE * CHILLER TONS * KW/TON * HOURS OF THERMAL OPERATION + ELECTRIC DEMAND RATE * CHILLER TONS * KW/TON * MONTHS OF OPERATION=	$18,900.00

COGENERATION COSTS:

FUEL:	COGEN RATE * CONSUMPTION/HOUR * HOURS OF ELECTRIC OPERATION=	$25,935.00
MANITENANCE:	MAINTENANCE COST/HOUR * HOURS OF ELECTRIC OPERATION=	$6,000.00

COGENERATION SAVINGS/YEAR: SUM OF AVOIDED COSTS - COGENERATION COSTS= ====> $22,965.00

PERCENT SAVINGS => 41.83% SIMPLE PAYBACK: ====> 5.23 YEARS

COGENERATION SCREENING ANALYSIS

DATA PROJECT 5

16-Jun-87

by: JIM PHILLIPS

EQUIPMENT DATA:		ENERGY DATA:	
Generator Size:	100 KW	Gas Rate:	$3.50 per MCF
Recoverable Heat:	0.666 MMBH	Cogen Rate:	$3.50 per MCF
Fuel Consumption:	1.235 MCFH	Electric Rate	
Maintenance Cost:	$1.00 per Hour	Demand:	$0.00 per KW
Hours of Electric		Months:	0 Months
Operation:	6000 Hours per Year	Energy:	$0.0600 per KWH
Hours of Thermal			(FCA incl'd.)
Operation:	6000 Hours per Year	% Gas Thermal:	0 %
		% Electric Thermal	100 %
Estimated Cost:	$120,000 Installed	Chiller Tonnage:	60 Tons
		Chiller Eff.:	1.5 KW/Ton

AVOIDED ELECTRIC ENERGY COSTS:

DEMAND:	ELECTRIC DEMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION=	$0.00
ENERGY:	ELECTRIC ENERGY RATE * GENERATOR SIZE * HOURS OF ELECTRIC OPERATION=	$36,000.00

AVOIDED THERMAL ENERGY COSTS:

GAS PRODUCED:	GAS RATE * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION=	$0.00
ELECTRIC HEATING:	ELECTRIC ENERGY RATE * 293 KWH/MMBH * RECOVERABLE HEAT * HOURS OF THERMAL OPERATION + ELECTRIC DAMAND RATE * GENERATOR SIZE * MONTHS OF OPERATION=	$0.00
ELECTRIC COOLING:	ELECTRIC ENERGY RATE * CHILLER TONS * KW/TON * HOURS OF THERMAL OPERATION + ELECTRIC DEMAND RATE * CHILLER TONS * KW/TON * MONTHS OF OPERATION=	$32,400.00

COGENERATION COSTS:

FUEL:	COGEN RATE * CONSUMPTION/HOUR * HOURS OF ELECTRIC OPERATION=	$25,935.00
MANITENANCE:	MAINTENANCE COST/HOUR * HOURS OF ELECTRIC OPERATION=	$6,000.00

COGENERATION SAVINGS/YEAR: SUM OF AVOIDED COSTS - COGENERATION COSTS= $36,465.00

PERCENT SAVINGS => 53.31% SIMPLE PAYBACK: =========================> 3.29 YEARS